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WALL CLIMBING ROBOT USING PNEUMATIC SYSTEMS

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ABSTRACT

The present study explores a wall-climbing robot that uses pneumatic systems for efficient vertical movement. It employs suction-based adhesion to navigate vertical surfaces. The pneumatic system generates the suction force needed for adherence and controlled release. The robot's modular design allows adaptability to various surfaces, and it features sensors and a control system for stable and precise climbing. This robot is a promising solution for inspection, maintenance, and surveillance in challenging environments.

1. INTRODUCTION

Climbing robots are invaluable devices with applications in various fields such as maintenance and building inspections in the construction industry. These systems are typically deployed in environments where direct human access is either prohibitively expensive or extremely dangerous due to hazardous conditions. Vertically climbing robots that can autonomously navigate vertical surfaces offer significant advantages for both military and civilian purposes [1]. In military contexts, these robots can be positioned on tall buildings to serve as observation platforms, providing valuable intelligence. They can also assist in search and rescue operations, conduct unmanned clearance of hostile areas, and act as platforms for carrying firearms and explosives. For civilian applications, climbing robots are essential in construction, offering real-time feedback on the status of operations at high elevations.

Considerable research has been dedicated to the development of climbing robots, resulting in various experimental models. The two primary challenges in designing wall-climbing robots are their locomotion and adhesion methods. Regarding locomotion, there are various types are often considered. Such as; the crawler [1], the track-wheeled or wheeled [2, 3], the legged [4], and the omni-directional wheel climbing robot [5]. Based on adhesion methods, these robots are generally classified into four groups [6].

PWCRs operate using two primary approaches: adhesion and locomotion. The adhesion mechanism includes two main types: suction cups and negative pressure-thrust (NPT) [1]. Suction cups can be passive, creating a vacuum through physical pressure suitable for small robots, or active, using an external vacuum generator for a stronger grip preferred for high adhesion. The challenges with suction cups include potential vacuum leaks due to surface abnormalities, mitigated by using multiple suction cups. Smaller robots may use one cup per leg, while larger robots can have up to 50 suction cups. NPT functions like a suction cup without requiring a vacuum seal, utilizing a high-speed rotor to create negative pressure, which attracts the robot to the surface [6]. This method offers advantages such as non-destructive testing and a compact design, but it comes with increased complexity, weight, and power consumption. The locomotion mechanism in PWCRs can be leg-based, translational, or wheel-driven. Leg-based locomotion provides stepwise motion, multiple degrees of freedom, and obstacle avoidance, with designs including bipedal, which offers simpler control but limited speed and degrees of freedom, and quadrupedal, which provides more adhesion points and reduces the risk of adhesion loss at the cost of increased complexity. Translational locomotion involves sequential motion with two frames moving alternately, inspired by caterpillar movement, offering simpler control but facing challenges with size and speed. Wheel-driven motion, often used in NPT-based PWCRs, allows for continuous motion but faces challenges such as poor obstacle avoidance and slipping risks. Implementations of wheel-driven motion include omni-directional wheels, independently controlled wheels, belt-driven systems, and conventional four-wheel configurations [5].

2. DESIGN AND FABRICATION

To design a pneumatic wall-climbing robot, start by identifying the requirements and objectives, considering factors such as size, weight, climbing mechanism, payload capacity, and desired features. Open Fusion 360 and create a new design file, selecting the appropriate units and workspace. Use Fusion 360's sketching tools to design the robot's mechanical structure, creating 2D profiles and extruding them into 3D shapes, ensuring proper shape, weight distribution, and structural integrity. Choose a climbing mechanism, such as suction cups, magnets, or gripping devices, and integrate it into the robot’s structure to ensure secure adhesion to vertical surfaces. Identify necessary actuators and joints for movement, designing these components with consideration for range of motion, strength, and stability. Finally, use Fusion 360's assembly environment to assemble and test these components.

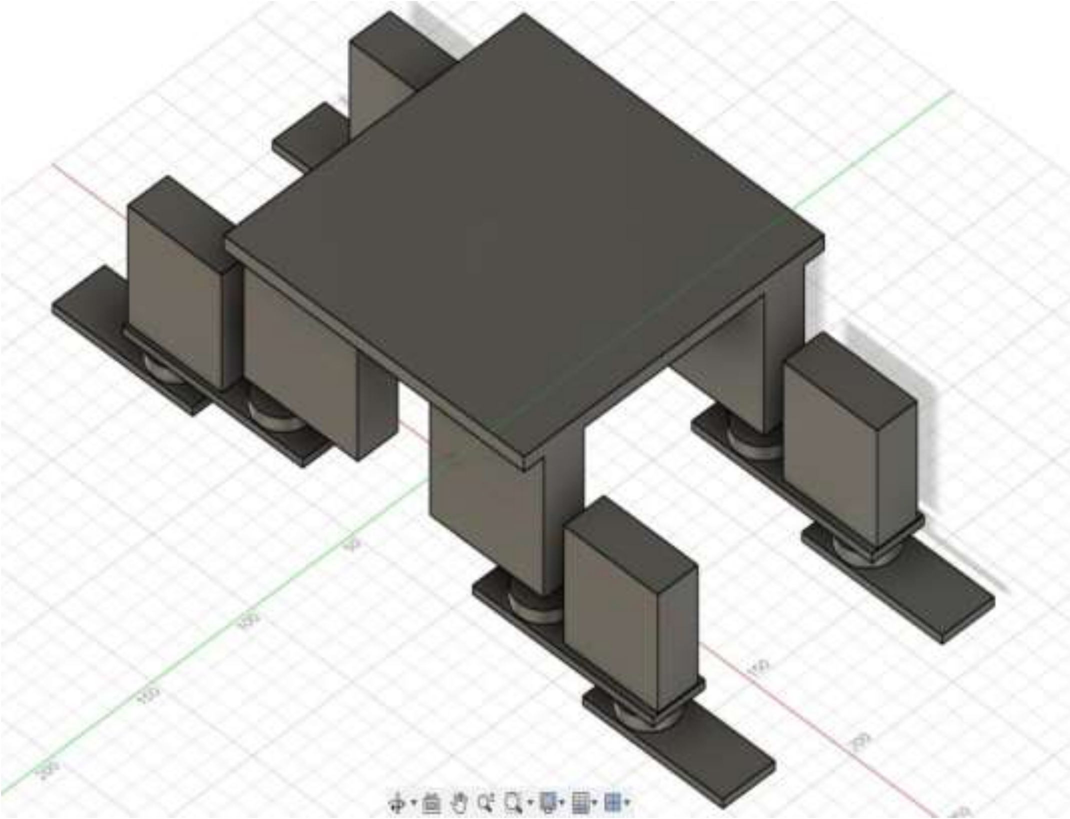

Fig.1 3D MODEL IN FUSION 360

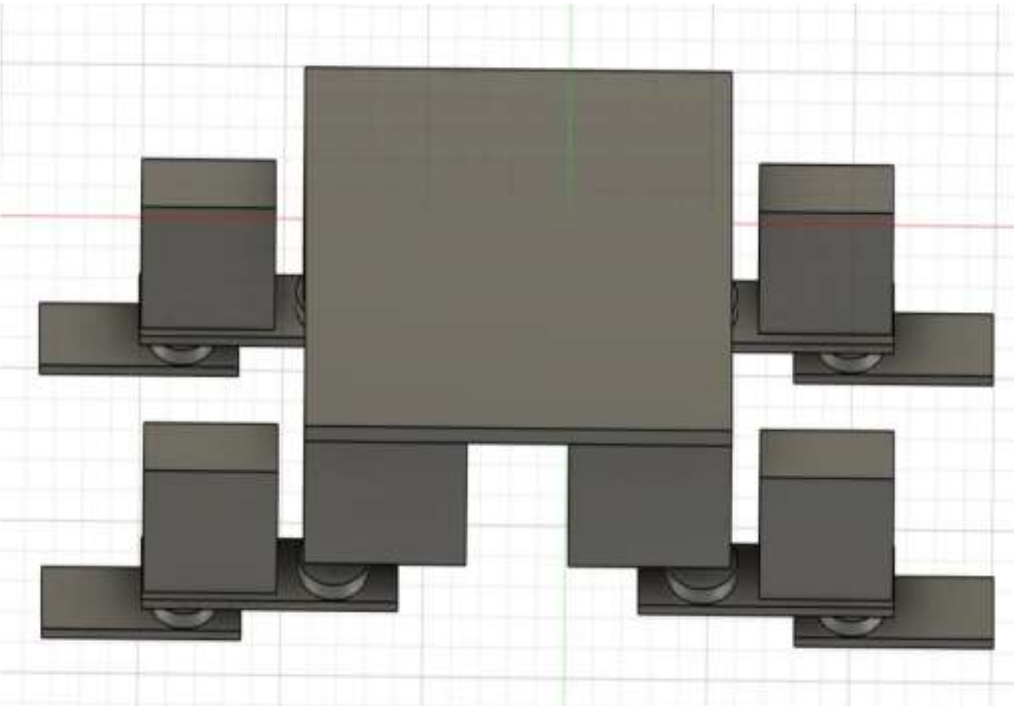

Fig.2 3D MODEL TOP VIEW IN FUSION 360

3. METHODOLOGY

To design and conceptualize a pneumatic wall-climbing robot, start by defining its requirements and objectives, focusing on climbing capabilities, payload capacity, and surface adaptability. Develop a conceptual design that incorporates pneumatic systems, such as suction cups for wall adherence. Next, select suitable pneumatic components like air compressors, valves, actuators, and suction cups, ensuring they are compatible with the robot's size, weight, and pressure range. During the robot's construction, assemble the framework and mechanical structure using lightweight and rigid materials, and integrate the selected pneumatic components with proper connections and alignment. Design a suction system that generates sufficient wall adhesion, considering the material, size, and shape of the cups, and develop a sealing mechanism with sensors to monitor suction force. Integrate the pneumatic system by connecting components such as the air compressor, valves, and actuators, ensuring proper air supply and pressure regulation for reliable operation. Develop a control system to manage the robot's movements and suction force, programming microcontrollers or using sensors and actuators for feedback and control. Test the robot on various wall surfaces to evaluate climbing performance, optimizing pneumatic system parameters like suction force and response time for efficiency and stability. Implement safety measures, including emergency stop mechanisms and fail-safe systems, to prevent accidents and protect the robot and its surroundings. Finally, refine the design based on test results and user feedback, making iterative improvements to enhance performance, reliability, and ease of use.

4. RESULTS AND DISCUSSION

The Wall Climbing Robot using pneumatic systems demonstrated impressive results, showing enhanced vertical mobility and gripping capabilities. It effectively adhered to surfaces using suction cups or adhesive materials by utilizing compressed air. The pneumatic system's ability to rapidly adjust pressure levels allowed for smooth attachment and detachment, further improving the robot's climbing performance.

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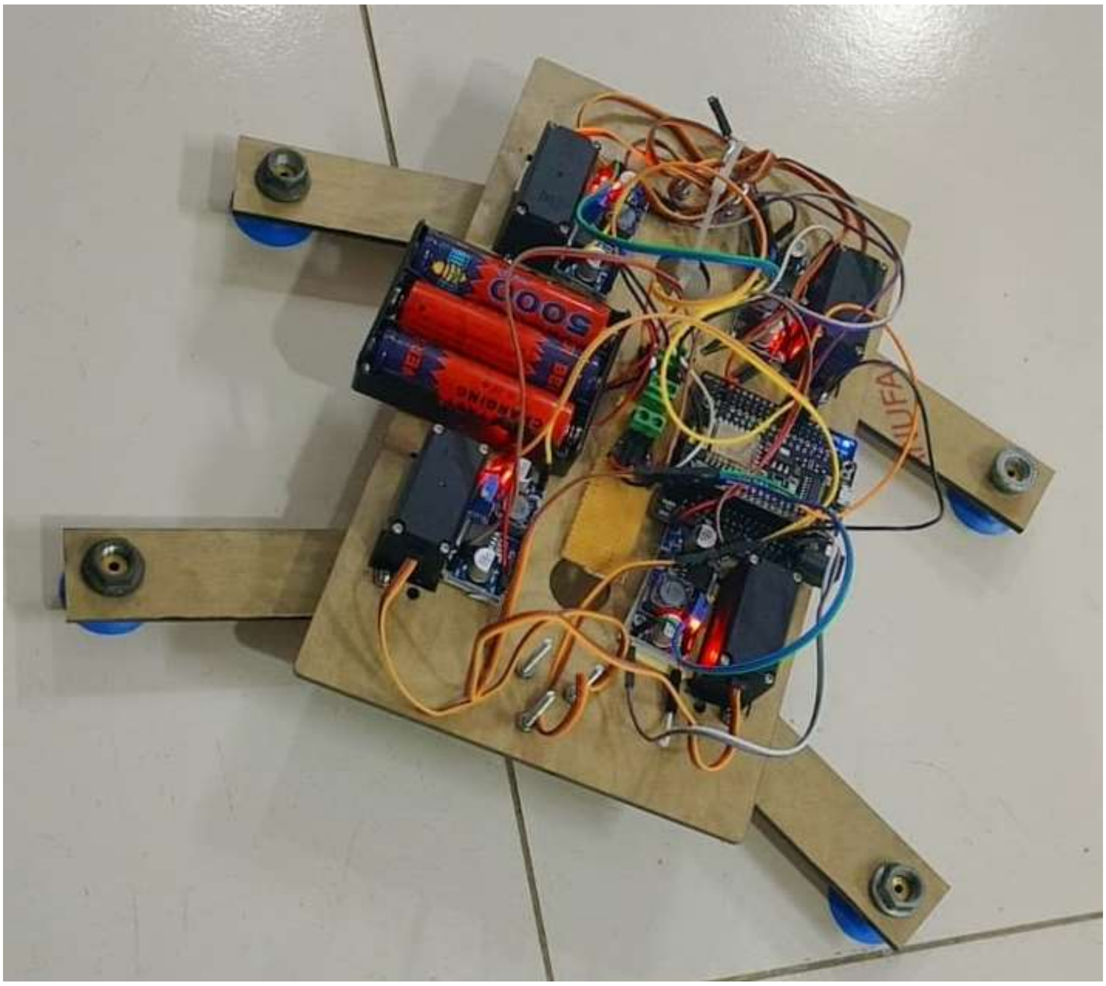

Fig.3 PROTOTYPE OF WALL CLIMBING ROBOT

5. CONCLUSION

The design and manufacture of the wall-climbing robot were successful. The required code is simple, and the components are readily available. The robot has a sturdy construction and can ascend vertical surfaces with a steady climbing stride. By switching out the end effectors, the robot can employ alternative adhesion methods. However, the aluminium construction, onboard battery pack, and suction pumps make it relatively heavy. To improve climbing performance, using acrylic structures and lighter batteries is recommended. End effector designs with various adhesion techniques should be conceived, produced, and tested. Additionally, implementing and testing several path planning algorithms is possible. Finally, the robot should be enhanced with environment awareness using various sensors and autonomous climbing capabilities to accomplish tasks in hard-to-reach areas where human access is challenging.

The future of wall-climbing robots using pneumatic systems is promising due to advancements in robotics, materials science, and automation. These robots can significantly impact various fields. In industrial maintenance and inspection, they can inspect high-rise building exteriors, bridges, and dams, detecting structural issues and improving safety while reducing the need for risky manual inspections. They can also maintain wind turbine blades, enhancing safety and minimizing downtime. In construction and infrastructure, these robots can automate facade cleaning and painting of skyscrapers and assist in construction tasks in hard-to-reach areas, such as carrying tools, welding, or bricklaying. For search and rescue operations, these robots can navigate rubble after natural disasters like earthquakes to locate survivors or assess structural damage and assist in firefighting by reaching high places in burning buildings to deliver fire suppression materials or aid in rescue operations.

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